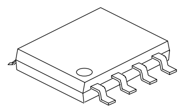
2.4A CURRENT 100V HIGH SIDE STEP-DOWN CONVERTER



SOP-8

■ DESCRIPTION

The UTC **UD100241** is an easy-to-use asynchronous step-down converter, which integrated low on-resistance high-side MOSFET to achieve better efficiency.

The **UD100241** can deliver 2.4A maximum output current with adjustable current limit, the startup current is as 2.5μA typically, easy to be used in low power design. The **UD100241** employs variable off-time control mode with frequency jitter to achieve easy EMI design.

The **UD100241** employs Built-in loop compensation network, so extra external compensation component is not needed, which minimized the solution BOM list. The **UD100241** innovated FB2 design, make the high side buck structure better. The transient and no-load performance are optimized, meanwhile the system solution size is minimized.

■ FEATURES

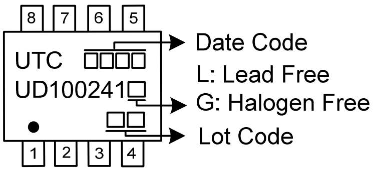
* 15V to 100V Wide Input Range
* 2.4A Maximum Continuous Output Current
* FB2 Control for Fast Transient Response
* Wide VCC operating range
* 100V/0.23Ω power MOSFET
* Frequency Jittering
* Adjustable Peak Current Limit
* Frequency Spread Spectrum
* 63μA Low Quiescent Current
* Low Audible Noise Control
* Full Protection including Over current protection (OCP), Short-circuit protection (SCP), Output Under-voltage (UVP), Output Over-voltage protection (OVP), Input Under-voltage lockout (ULVO), Over temperature protection (OTP)

■ ORDERING INFORMATION

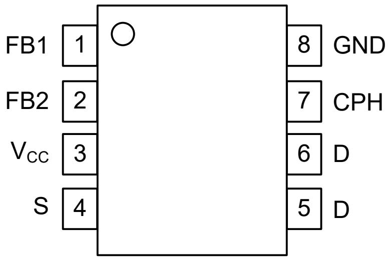
Ordering Number		Package	Packing
Lead Free	Halogen Free		
UD100241L-S08-R	UD100241G-S08-R	SOP-8	Tape Reel

UD100241G-S08-R (1)Packing Type (2)Package Type (3)Green Package	(1) R: Tape Reel (2) S08: SOP-8 (3) G: Halogen Free and Lead Free

■ MARKING



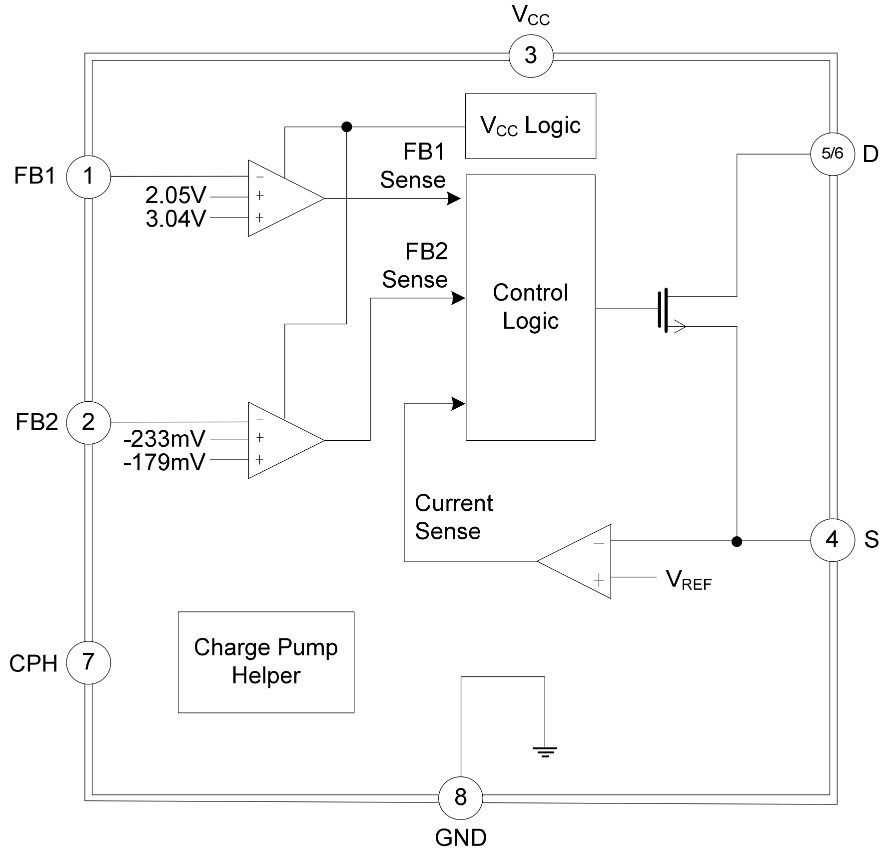
■ PIN CONFIGURATION



■ PIN DESCRIPTION

PIN NO.	PIN NAME	DESCRIPTION
1	FB1	**Feedback pin1.** This pin will sense the voltage of the output when freewheeling diode is conducting current, connect a resistor divider between OUT and chip GND to set the output voltage.
2	FB2	**Feedback pin2.** This pin will sense the output voltage at Hi-Z state and provides a programmable V_{OUT} operating threshold, connect a resistor divider between chip GND and output GND to set the threshold boundary.
3	V_{CC}	**IC internal logic circuitry power supply**, place 2.2μF decoupling capacitor close to this pin.
4	S	**Source node of the power MOS**, also served as the current sense pin.
5, 6	D	**Drain node of the power MOS.** In high-side buck configuration, connect this pin to VIN of the system.
7	CPH	**Charge pump helper.** Use CPH pin when output voltage is in the range of 2.5 to 4.5V. Float if not used.
8	GND	**IC ground.** In high-side buck configuration, it needs to be connected to the SW node after the current sense resistor.

■ BLOCK DIAGRAM



■ ABSOLUTE MAXIMUM RATING (T_A=25°C, unless otherwise specified)

PARAMETER	SYMBOL	RATINGS	UNIT
Power MOSFET Input Voltage, D to S	V_{IN}	-0.3 ~ 105	V
Power Supply for IC, V_{CC} to GND	V_{CC}	-0.5 ~ 32	V
Output Feedback Signal1, FB1 to GND	FB1	-0.5 ~ 4.5	μA
Output Feedback Signal1, FB2 to GND	FB2	-0.5 ~ 0	V
Power MOSFET Source, S to GND	S	-0.3 ~ 4.5	V
Junction Temperature	T_J	-55 ~ +150	°C
Storage Temperature	T_{STG}	-65 ~ +150	°C

Note: Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.

■ RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	RATINGS	UNIT
Output Current	I_{OUT}	0 ~ 2.4	A
Output Voltage	V_{OUT}	2.5 ~ 24	V
V_{CC} to GND	V_{CC}	2.5 ~ 30	V
Junction Temperature	T_J	-40 ~ +125	°C

Note: Guaranteed by design and engineering sample characterization.

■ THERMAL DATA (Note)

PARAMETER	SYMBOL	RATING	UNIT
Junction to Ambient	θ_{JA}	90	°C/W
Junction to Case	θ_{JC}	45	°C/W

Note: Measured on JESD51-7, 4-Layer PCB, and the PCB has no copper for thermal dissipation. Normal PCB with copper thermal resistance will be smaller.

■ ELECTRICAL CHARACTERISTICS (V_{IN}=12V, T_A=25°C, unless otherwise specified)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Vcc						
V_{CC} Clamped Voltage	V_{CC_Clamp}	I_{CC}=2mA	19	20		V
V_{CC} Over Voltage Protection Threshold	V_{CC_OVP}		28.5	30	32	V
V_{CC} Startup Threshold	V_{CC_Start}	V_{CC} Rises Up	9.2	9.7	10.3	V
V_{CC} Shutdown Voltage	V_{CC_Stop}	V_{CC} Ramps Down	4	4.15	4.3	V
V_{CC} Startup Current	I_{ST}	V_{CC}=V_{CC_Start} -1V T_J= -40° ~ +125°C		2.5	10	μA
V_{CC} Quiescent Operation Current	I_{OP}	V_{CC}=19V, V_{FB}=2.2V		63		μA
FB1						
FB1 Regulation Reference Voltage	V_{FB1_REF}		1.95	2.05	2.15	V
FB1 Sample Blanking Time After Power MOS Off	T_{Sample_BLK} (Note 1)			1.4		μs
FB1 OVP Threshold	V_{FB1_OV}			3.04		V
FB2						
FB2 Active Threshold	V_{FB2ACT} (Note 1)			-30		mV
FB2 Over Voltage Threshold	V_{HOLD}		-244	-233	-221	mV
FB2 Standby Mode Wakeup Threshold	V_{WAKEUP}		-191	-179	-167	mV
FB2 Sample Blanking Time	T_{SAMPLE_BLK} (Note 1)	After ZC is Detected	6			μs
MAX FB2 Sample Blanking Time	T_{SAMPLE_BLKMAX}	After Power MOS off		83		μs
CURRENT SENSE						
Max Current limit Voltage	$V_{CS\_PK\_MAX}$		290	307	325	mV
Min Current Limit Voltage at Low Load State	$V_{CS\_PK\_MIN}$			0.4		$V_{CS\_PK\_MAX}$
Leading Edge Blanking Time	T_{LEB} (Note 1)			250		ns
INTERNAL POWER MOSFET						
Drain-Source Turn-On Resistance	R_{DSON}			0.23		Ω
FREQUENCY & TIMING PART						
Minimum off Time	t_{MIN_OFF}		6.2	6.8	7.5	μs
Maximum Turn on Time	t_{ON_MXA}			22		μs
Maximum Turn off Time	$t_{OFF\_MAX\_ECO}$	FB2 Enabled		20		ms
Maximum Turn off Time	t_{OFF_MAX} (Note 1)	FB2 Disabled		670		μs
OVER TEMPERATURE PROTECTION (OTP)						
Over Temperature Threshold	T_{OTP} (Note 2)			140		°C

Notes: 1. Guaranteed by Design.
2. Not tested in production and derived from bench characterization.

■ FUNCTION DESCRIPTIONS

COT control loop operation

UD100241 is peak current control buck converter. The power MOSFET's ON time is controlled by the peak current limit. IC controls the OFF time to regulate the output voltage. **UD100241** switching frequency will decrease with load decreasing. As a result, **UD100241** can achieve excellent light load efficiency. **UD100241** can work in continuous conduction mode (CCM) and discontinuous conduction mode (DCM) based on the load current condition. **UD100241** has Built-in loop compensation, no need for extra external compensation components, which makes the loop design simplified.

Startup and Input Under Voltage Lockout

Before IC starts switching, **UD100241** V_{CC} start current is as low as 2.5µA typ. V_{CC} can be charged by the pull-up resistor from V_{IN}. IC remains low start current consumption until V_{CC} charged above (V_{CC_START}) 9.7V. After V_{CC} charged above V_{CC_START}, IC starts switching output will rise up and supply the V_{CC} via the external diode. The V_{CC} supply voltage needs to be higher than (V_{CC_STOP}) 4.15V.

When V_{CC} voltage falls below the V_{CC_STOP}, **UD100241** will stop switching to avoid abnormal operation and V_{CC} will be recharged up to V_{CC_START} again, **UD100241** will restart then. Proper pull-up resistor needs to be designed to get the desired V_{IN} startup time delay, meantime needs to pay attention to the power derating of the pull-up resistor.

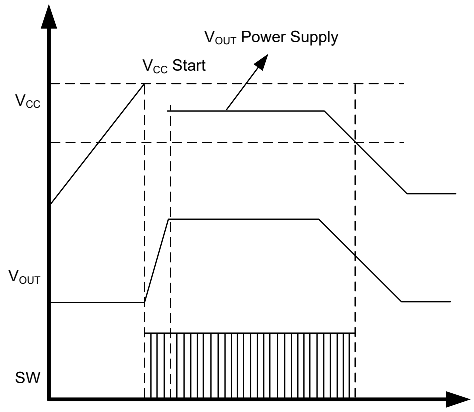


Figure 1. Startup Timing

Output Voltage Regulation

UD100241 can regulate the output voltage under different load and input voltage condition. Whenever High-side (HS) power MOSFET is off, FB1 will become the sensor of the output voltage. After a period of sense blanking time when the HS power MOSFET is off, V_{OUT} will be sensed via FB1 and sent to internal error amplifier. The output of the error amplifier will control the timing of next on pulse, also it controls the peak current. To keep the V_{OUT} stable at different load condition: it adjust the switching frequency and IPK to regulate the output voltage.

In low standby power applications, FB2 function is strongly recommended to improve system's light load efficiency, otherwise, a small resistance dummy load is needed to avoid V_{OUT} overshoot at no load condition.

UD100241 will enter Eco mode under extremely light load or no-load condition to avoid IC cannot monitor FB1 for a long time. In Eco mode, if FB2 function is enabled, the maximum off time is 20ms typically, otherwise, the maximum off time is 670µS typically.

FB2 pin related Output Under Voltage Protection and Over Voltage Protection

UD100241 has innovated FB2 to improve the load transient performance of High-side buck structure design. When IC enters Hi-Z state, FB2 monitors the V_{OUT} via the shunt resistor from V_{OUT}+ to V_{OUT}-. In Hi-Z state, chip GND is connected to V_{OUT}+ through the inductor, so FB2 is the sensor of V_{OUT} at this time, in normal operation, FB2 pin voltage is designed between -179mV and -233mV. If FB2 pin voltage is higher than -179mV in Hi-Z state, IC will consider it to be V_{OUT} under voltage which might be caused by load transient, IC will start a new pulse immediately to avoid V_{OUT} undershoot. On the other hand, if FB2's voltage is lower than -233mV in the Hi-Z state, then IC will consider it to be V_{OUT} over voltage. No pulse will be allowed any more to avoid V_{OUT} overshoot even if the off time is longer than the MAX off time 20ms.

Connect the FB2 pin to chip GND to disable the FB2 detection.

■ FUNCTION DESCRIPTIONS (Cont.)

FB1 pin related Output Under Voltage Protection and Over Voltage Protection

At each switching cycle, **UD100241** will sense the output voltage when freewheeling diode is conducting current:

if the sensed FB1 voltage exceeds V_{FB1_OV} threshold (3.04V typically), IC will stop switching immediately, V_{CC} will be discharged down to entry hiccup protection.

If the sensed FB1 voltage continues below internal V_{TH} threshold (After soft-start finished) for four switching cycles, IC will discharge V_{CC} to entry hiccup protection immediately. this hiccup protection will last until the over-voltage or under-voltage condition is removed.

VIN low protection when FB2 function is disabled

When FB2 pin is connected to chip GND, **UD100241** provides V_{IN} low protection to prevent the IC from damage under extreme working conditions. During normally switching, the on time of power MOSFET is increasing with input voltage decreasing. If V_{IN} is too low, T_{ONMAX} (22μS typically) will be reached before I_{PK}. If this happens four times in a row, V_{CC} will be discharged to restart the IC until V_{IN} raised high enough or load current reduced enough, IC will back to normally switching again.

Feedback Open Output Over Voltage Protection

UD100241 can achieve V_{OUT} over voltage protection in feedback open condition via V_{CC} pin. **UD100241** V_{CC} working range is from 4.15V to 30V. Because V_{CC} voltage is bias by V_{OUT} through the external diode, V_{CC} voltage will increase together with V_{OUT}. When V_{CC} voltage goes above 30V, the V_{CC} over voltage protection will be triggered. IC will be shut down and stop switching. V_{CC} will be discharged by an internal 6mA current source. IC will stops switching until V_{CC} drops to V_{CC_STOP}. Then the internal 6mA current source will be disconnected and V_{CC} will be recharged up by the external pull up resistor. IC restart when V_{CC} voltage rise above V_{CC_START}. **UD100241** repeats this operation cycle until the V_{CC} over-voltage condition disappears and the output voltage rise smoothly back to the regulation level.

Feedback Open Output Over Voltage Protection

The **UD100241** sensed the current in HS power MOSFET through the external R_{CS} resistor. When the sense voltage reaches V_{CS_PK}, IC will shut down the power MOSFET. The peak current determined by the R_{CS} resistor. The maximum I_{PK} is $V_{CS\_PK/RCS}$. When load decreases, the minimum I_{PK_MIN} is $V_{CS\_MIN/RCS}$=V_{CS_PK}/2.5xR_{CS} .To avoid V_{CS_PK} triggered by the spike current cause by the parasitic capacitance and reverse recovery current of the freewheeling diode, and result in HS power MOSFET falsely off, **UD100241** implement a blanking time (Tblk) after HS power MOSFET turns on, during the blanking time, the current limit comparator will be disabled. The I_{PK} of **UD100241** can be programmed by the external R_{CS} resistor.

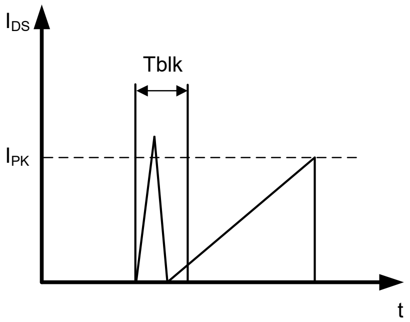


Figure 2. Current Sense Blanking

Over Current and Short-Circuit Protection

The **UD100241** max output current is limited by minimum off time and peak current limit, with the load current increasing, the IC switching frequency will increase until reaches the minimum off time, if keep increasing the load current, the frequency cannot be increased furthermore and V_{OUT} starts to drop, due to V_{CC} is biased by V_{OUT} via the diode, V_{CC} will drop following the V_{OUT}. When V_{CC} voltage drops below the V_{CC_STOP}, IC stops switching and enter hiccup protection. Then V_{CC} voltage will be recharged by the pull-up resistor from V_{IN} to V_{CC}. IC will restart after V_{CC} exceeds V_{CC_START} again. **UD100241** repeats this operation cycle until the over-current condition is removed, then V_{OUT} will rise up smoothly to the regulation level.

■ FUNCTION DESCRIPTIONS (Cont.)

Switching Frequency and Audible Noise Reduction

UD100241 is peak current mode control. IC switching frequency will decrease with load decreasing to achieve excellent light load efficiency. When **UD100241** switching frequency is much higher than 20KHz, the switching frequency can be estimated by below two formulas:

$$F_{SW}=\frac{2(V_{IN}-V_O)}{L\times I^2_{PK}}\times\frac{V_O\times I_O}{V_{IN}},DCM \qquad (1)$$

$$F_{SW}=\frac{(V_{IN}-V_O)}{2L\times(I_{PK}-I_O)}\times\frac{V_O}{V_{IN}},CCM \qquad (2)$$

The **UD100241** will gradually reduce the peak current limit to minimum 0.4 times of the max peak current limit setting by sense resistor when switching frequency drops below 20KHz. The inductor current can be greatly reduced in this condition and the load range in which will generate the audible noise will become smaller. After switching frequency entered the audible noise range, the smaller inductor energy will reduce the noise cause by the inductor vibration.

Green Mode Operation

UD100241's switching frequency is decreasing with load decreasing, as a result, **UD100241** can achieve excellent light load efficiency, different with traditional burst mode, the **UD100241** switching period can be automatically decreased to 20ms maximum with FB2 function enabled, so the light load ripple voltage will be optimized.

Low Output Voltage Operation

When output is set in the range of 2.5V to 4.5V, the V_{CC} voltage will be too low to drive the internal MOSFET. CPH pin can be used to charge pump the V_{CC} voltage to two times of the output voltage with below circuit.

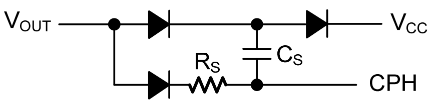


Figure 3. External Charge Pump Circuit for 2.5V to 4.5V Output

Commonly recommend R_S=1kΩ, and C_S=470nF.

EMI Reduction

UD100241 achieves the switching frequency jitter by modulate the V_{CS_PK}. By doing this, EMI noise peak caused by the switching frequency noise will be greatly reduced, which will help to sample the EMI design and reduce the solution BOM cost.

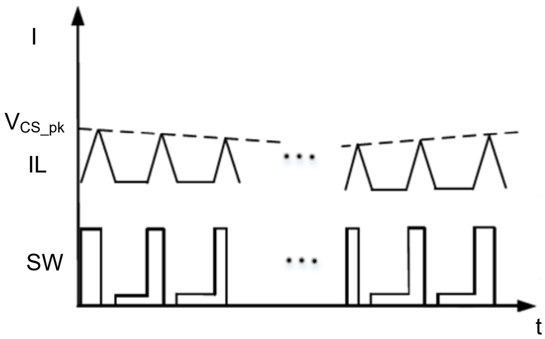
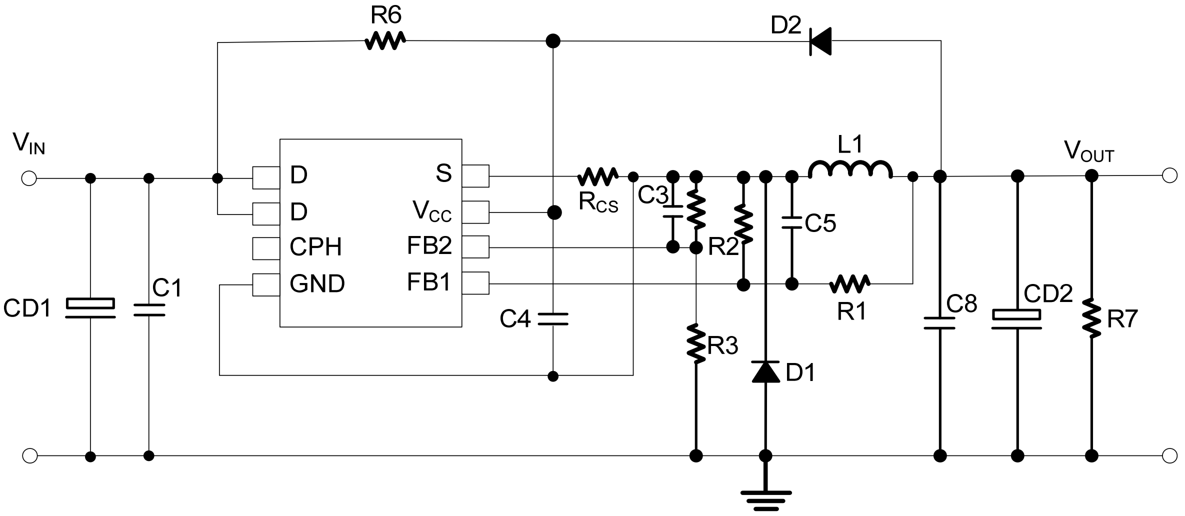


Figure 4. Frequency Spread Spectrum

Over Temperature Protection

UD100241 has built-in accurate over temperature protection. It monitors the controller's temperature and improves the system reliability. Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the controller's temperature exceeds 140°C, IC will stop switching and system will repeat discharge and recharge V_{CC} cap to achieve the protection, until over-temperature condition is removed, then IC will back to normally switching.

■ APPLICATION INFORMATION



Setting the FB1 Resistor

UD100241 output voltage can be set by the external resistor dividers on FB1 pin. Equation as below:

$$V_O=2.05\times(1+\frac{R_1}{R_2})-0.4 \quad (3)$$

Where 0.4V is the forward voltage drop of the freewheeling Schottky diode, recommend to use Schottky diode here to achieve better efficiency.

Normally use a value around 20K for R1 resistor. To avoid the noise to the FB1 pin, recommend to use a 10pF/50V capacitor in parallel with R1 resistor. For this design example, choose 22K for R1,36K for R2, so the operating output voltage is:

$$V_O=2.05\times(1+\frac{36K}{22K})-0.4=5V \quad (4)$$

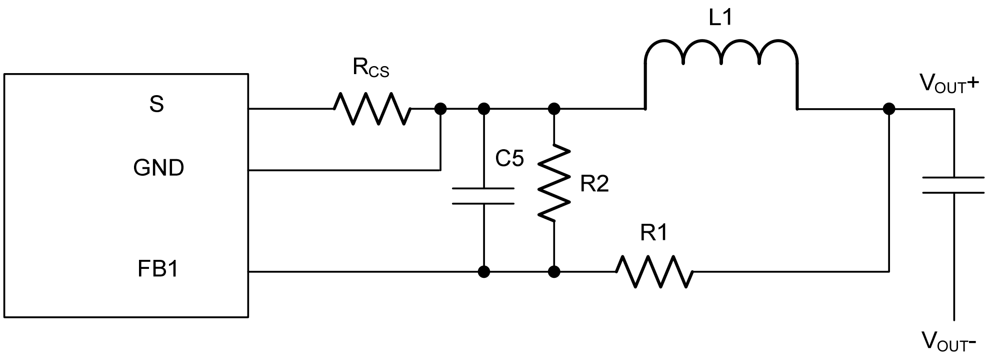


Figure 5. FB1 Feedback Network

■ APPLICATION INFORMATION (Cont.)

Setting the FB2 Resistor

FB2 can be used to set the wake-up voltage under no-load condition. Connect the FB2 to chip GND will disable the FB2 detection. If FB2 wake-up threshold is not triggered within t_{OFF} max 20ms, then IC will work under 20ms typical switching cycle. If FB2 wakeup threshold is triggered within 20ms, **UD100241** will wake up and start normal operating immediately to achieve fast loop response. If FB2 voltage is lower than -0.233V, no pulse will be allowed any more to avoid V_{OUT} overshoot higher even if the off time is longer than the MAX off time 20ms. For this design example, choose 5.1K for R4, 130K for R3, So in no-load output voltage max value is determined by below formula:

$$V_{O\_MAX}=0.233\times(1+\frac{R3}{R4})=0.233\times(1+\frac{130}{5.1})=6.17V \quad (5)$$

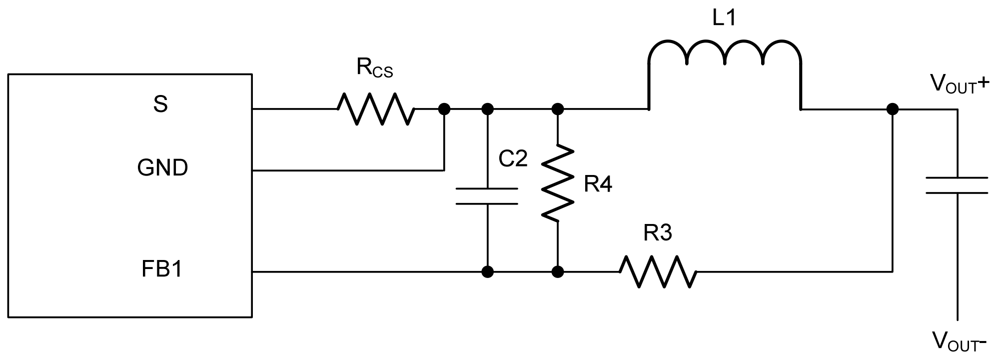


Figure 6. FB2 Feedback Network

Wake-up voltage is set by FB2. When FB2 below 0.179V IC will wake-up. For this design example, choose 5.1K for R4, 130K for R3, so wake up voltage can be set by below formula:

$$V_{O\_MIN}=0.179\times(1+\frac{R3}{R4})=0.179\times(1+\frac{130}{5.1})=4.74V \quad (6)$$

Please refer to below table for feed-back-loop parameters selection:

	V_O=5V	V_O=12V
R1	36K	110K
R2	22K	22K
R3	130K	330K
R4	5.1K	5.1K

Setting the Max Output Current

If IC works in CCM mode, so the max output current will be determined by below formula:

$$I_{O\_MAX}=\frac{I_{PK}}{2}-\frac{V_{IN}-V_O}{2\times L\times F_{SW}}\times\frac{V_O}{V_{IN}} \quad (7)$$

If IC works in DCM to CCM critical mode under max output condition. So the max output current will be determined by below formula:

$$I_O=\frac{I_{PK}}{2} \quad (8)$$

While IPK is the inductor peak current. IPK is determined by Rcs with below formula:

$$I_{PK}=\frac{V_{CS\_PK}}{R_{CS}} \quad (9)$$

Note: need to choose 1% accuracy with good temperature coefficient resistor for Rcs to achieve good production and over temperature consistency.

■ APPLICATION INFORMATION (Cont.)

Selecting the Inductor and Set the Switching Frequency

In this case the switching frequency can be estimated by below formulas:

$$F_{SW}=\frac{2(V_{IN}\text{-}V_O)}{L\times I^2_{PK}}\times\frac{V_O\times I_O}{V_{IN}},DCM \tag{10}$$

$$F_{SW}=\frac{(V_{IN}\text{-}V_O)}{2L\times(I_{PK}\text{-}I_O)}\times\frac{V_O}{V_{IN}},CCM \tag{11}$$

For this design example, if V_{IN}=60V, V_O=5V, I_{PK}=3.8A, L=68μH:

when Io=0.1A, IC works in DCM, I_{PK} will be decreased to 0.4 times of that in heavy load condition, so the switching frequency under 0.1A load current can be calculated as:

$$F_{SW}=\frac{2\times(V_{IN}\text{-}V_O)}{L\times I^2_{PK}}\frac{V_O\times I_O}{V_{IN}}=5.83kHz \tag{12}$$

When I_O=2A, IC works in CCM, so the switching frequency under 2A load current can be calculated as:

$$F_{SW}=\frac{(V_{IN}\text{-}V_O)}{2L\times(I_{PK}-I_O)}\times\frac{V_O}{V_{IN}}=18.72kHz \tag{13}$$

Consider the EMI performance and PCB solution size. Recommend to set the switching frequency below 100KHz, too fast switching frequency will result in thermal and EMI issue, too low switching frequency will increase the solution size and BOM cost.

Selecting the Startup Resistor and V_{CC} Capacitor

The V_{CC} startup current of **UD100241** is 2.5μA typical, suggest to choose a proper pull-up resistance to get larger than 10μA V_{CC} charge current. Within reasonable range, use larger pull-up resistance can decrease the no-load consumption, meanwhile the start-up delay time will be larger, and vice versa. When freewheeling diode is Schottky type, recommend not to choose too large startup pull-up resistor in case of startup failure under high ambient temperature application. For commonly use, suggest to choose a 100K to 1MΩ pull-up resistor.

During startup period, after IC starts switching, V_{CC} will consume more current and V_{IN} side can't provide the whole energy due to pull-up resistor limitation, thus parts of the energy will be obtained from V_{CC} capacitor, until V_{OUT} rises high enough and be able to supply V_{CC} through external diode. If output capacitance is too large, V_{CC} capacitance can't be too small to avoid the situation that V_{CC} drops below V_{CC_STOP} before V_{OUT} become high enough to supply V_{CC}. For commonly use, suggest to choose a 2.2μF to 4.7μF V_{CC} capacitor

Selecting the Output Capacitor

Output capacitor is used to maintain the output voltage. The steady state ripple voltage can be calculated with below formula:

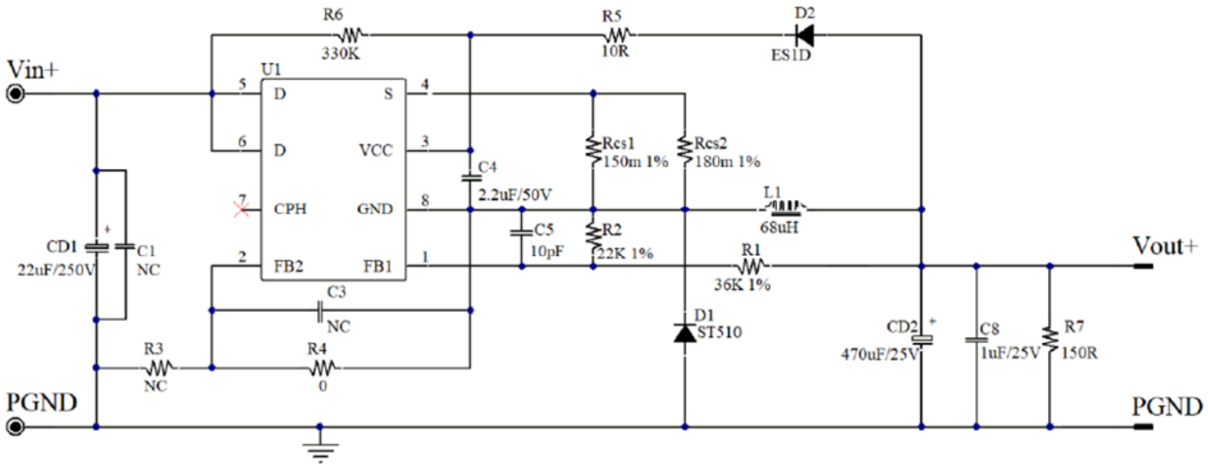
$$V_{OUT\_ripple}=\frac{I_{PK}}{8F_{SW}\times C_{OUT}}+I_{PK}\times R_{ESR} \tag{14}$$

Recommend to choose low ESR Aluminum electrolytic capacitor to reduce the output ripple voltage.

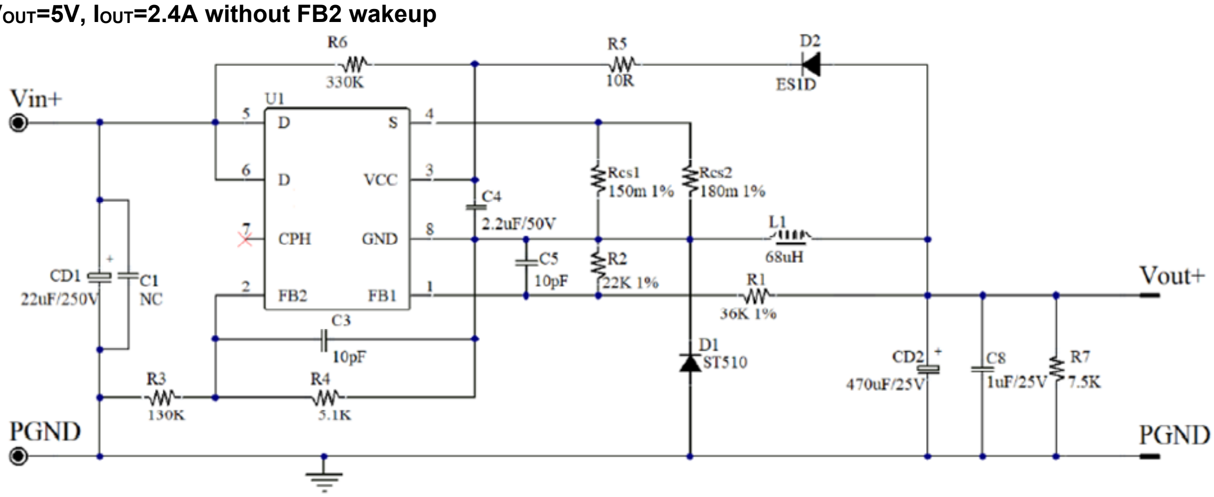
Due to the FB2 design, **UD100241** has good transient performance, doesn't need to use too large output capacitor to achieve the transient requirement. The output capacitance can be reduced with the maximum output current reducing.

■ TYPICAL APPLICATION CIRCUIT

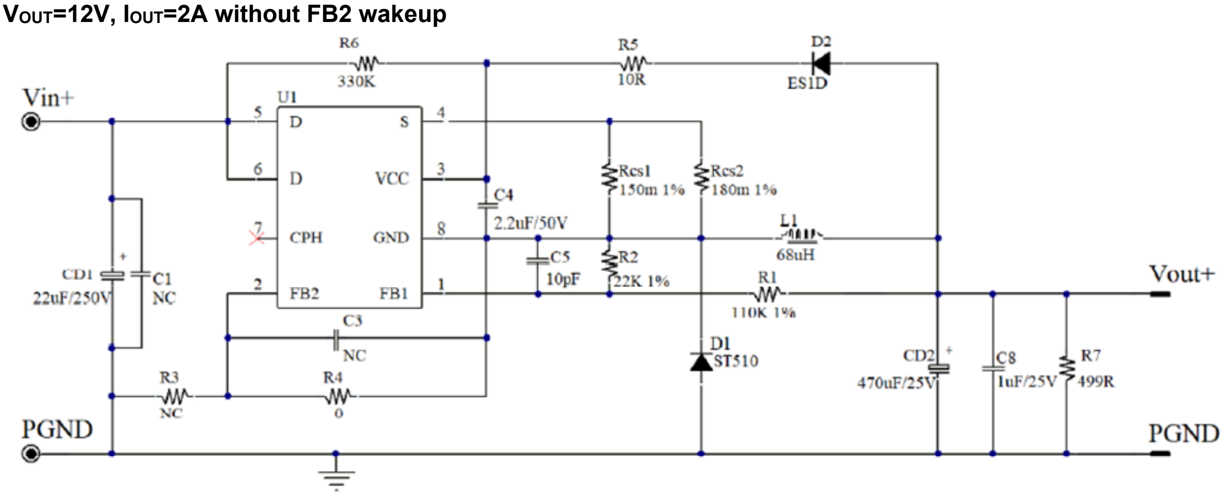
V_{OUT}=5V, I_{OUT}=2.4A without FB2 wakeup



V_{OUT}=5V, I_{OUT}=2.4A without FB2 wakeup

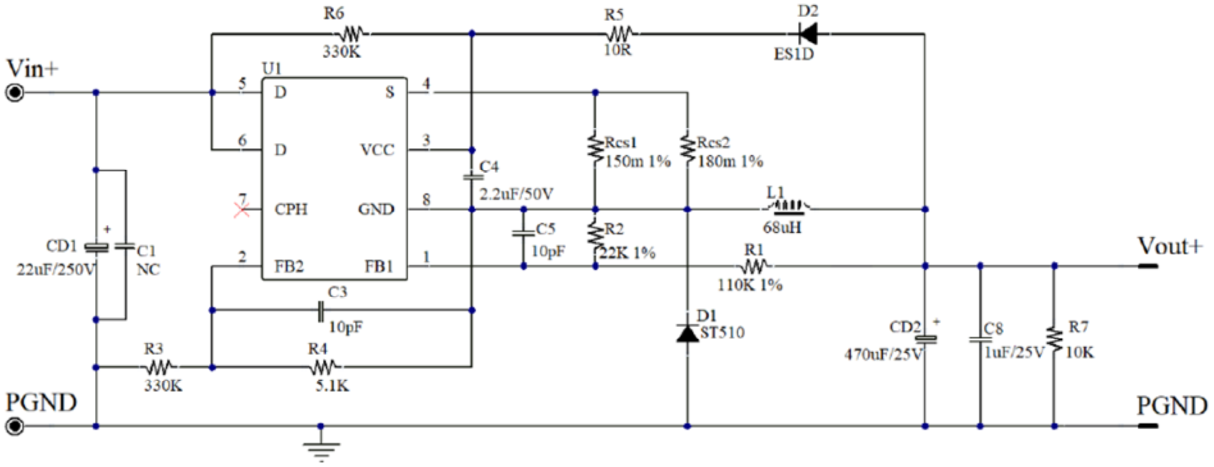


V_{OUT}=12V, I_{OUT}=2A without FB2 wakeup



■ TYPICAL APPLICATION CIRCUIT (Cont.)

V_{OUT}=12V, I_{OUT}=2A without FB2 wakeup



Note: Pay attention to the power derating of the dummy load R7 when FB2 function is disabled.